Designations for the 2006 $PM_{2.5}$ Standards: Evaluating the Nine Factors in Setting Nonattainment Area Boundaries

Part 2 – Conceptual Model for Evaluating High $PM_{2.5}$ Days and its Influencing Emission Sources

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The 9 Designation Factors

To Help Determine Nearby Area of Influence for 24-hr NAAQS Violations

Air Quality is one of the most Important Designation Factors

Topics to be Covered

- Conceptual model for high PM days
- Seasons when exceedances occur
- Composition of the high days
- Analytical tools
  - SLICE technique - for evaluating urban contributions to high days
  - Residence time analysis – for assessing nearby contributing source regions using back trajectories and emissions data
  - Gradient analysis – for identifying days with potential high source-oriented impacts

Conceptual Model for High PM2.5 Days

- How to define high PM2.5 days?
- What is the typical “daily increment” for high PM days in relation to the annual average?
- What is the urban contribution above regional levels?

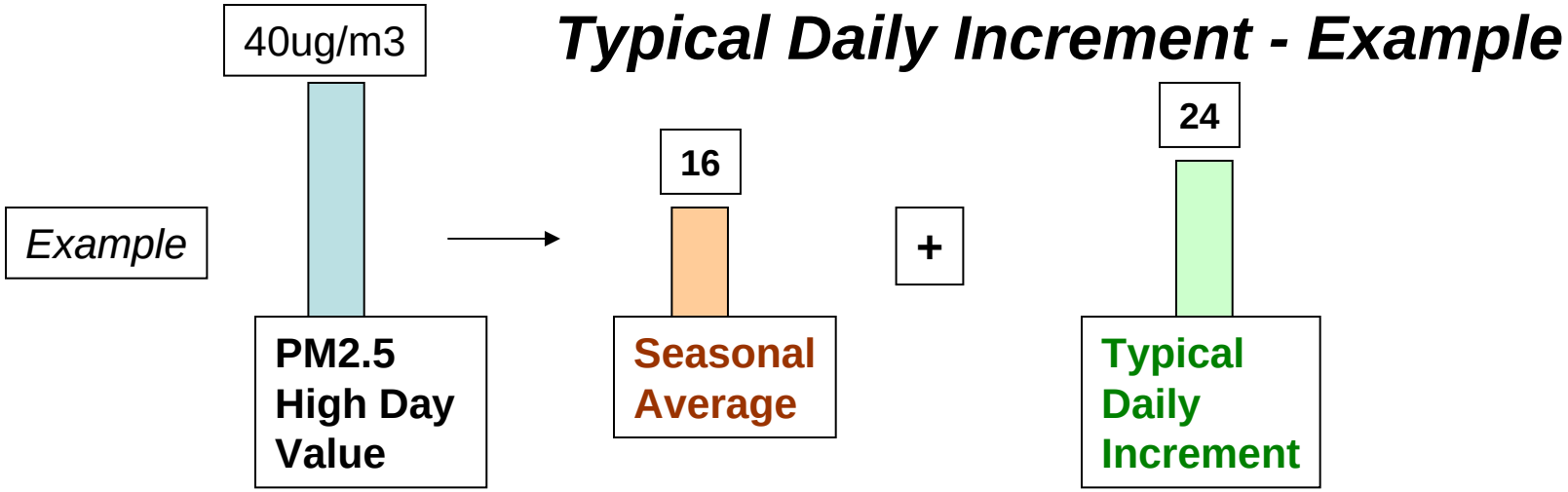
Conceptual Model for High PM2.5 Days

What high PM2.5 days to consider?

- "High PM2.5 Days" Associated with the 98th percentile
  - ✓ Not just one day per year
  - ✓ Select all candidate days
  - ✓ e.g. top 5% or days > 30 - 35ug/m3
  - ✓ Summarize by season to distinguish varying conditions

Conceptual Model for High PM2.5 Days

High Daily PM2.5 has Urban and Regional Components

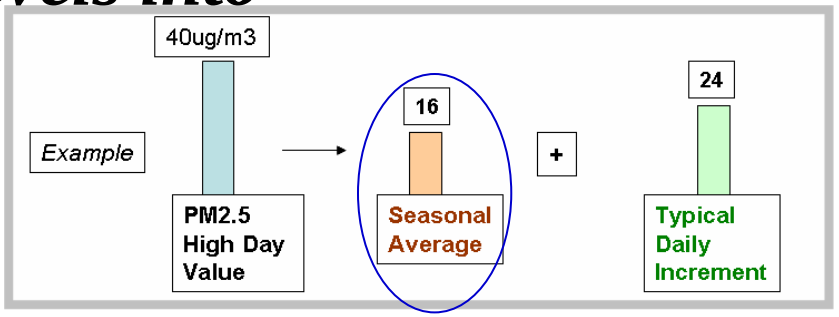


- The annual average PM2.5 (urban background) is the stuff that is there on a day-to-day basis.
  - –Comes from nearby and more distant areas
  - –Can be estimated by seasonal average PM2.5 concentration of non-high days
  - –Includes contributions from all nearby surrounding counties
  - –Can be estimated using the traditional urban increment approach
- The daily increment (on top of annual average urban background) also has regional and local contributions.

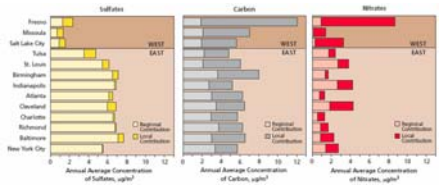
- Key issue: what counties and sources from the urban area contribute to the typical daily increment?

Conceptual Model for High PM2.5 Days

An approach to partition typical levels into urban and regional components



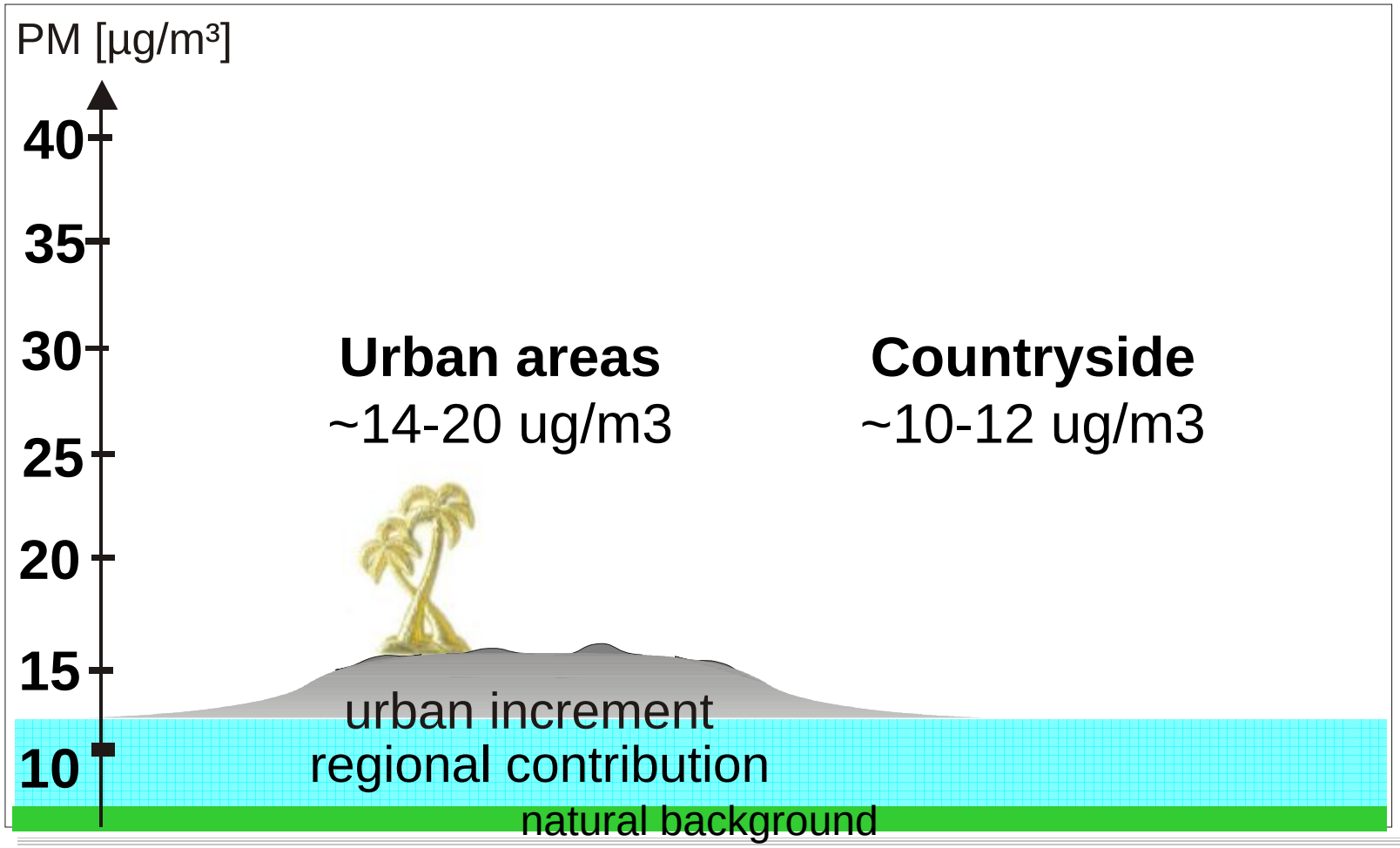
- Urban Increment Analyses as used in 2004/2005 PM2.5 Designations



- Urban sources in the Eastern US contribute at least 4-6 ug/m3 to annual average PM2.5
  - Probably even larger urban contribution in western US cities
- Carbon is significant component of average PM2.5 mass, but metro area emissions typically are much less than SO2 and NOx
  - Weighted emissions score developed to give additional weight to nearby direct carbon emissions as they contribute to the urban background

Air Quality - Annual Average PM2.5

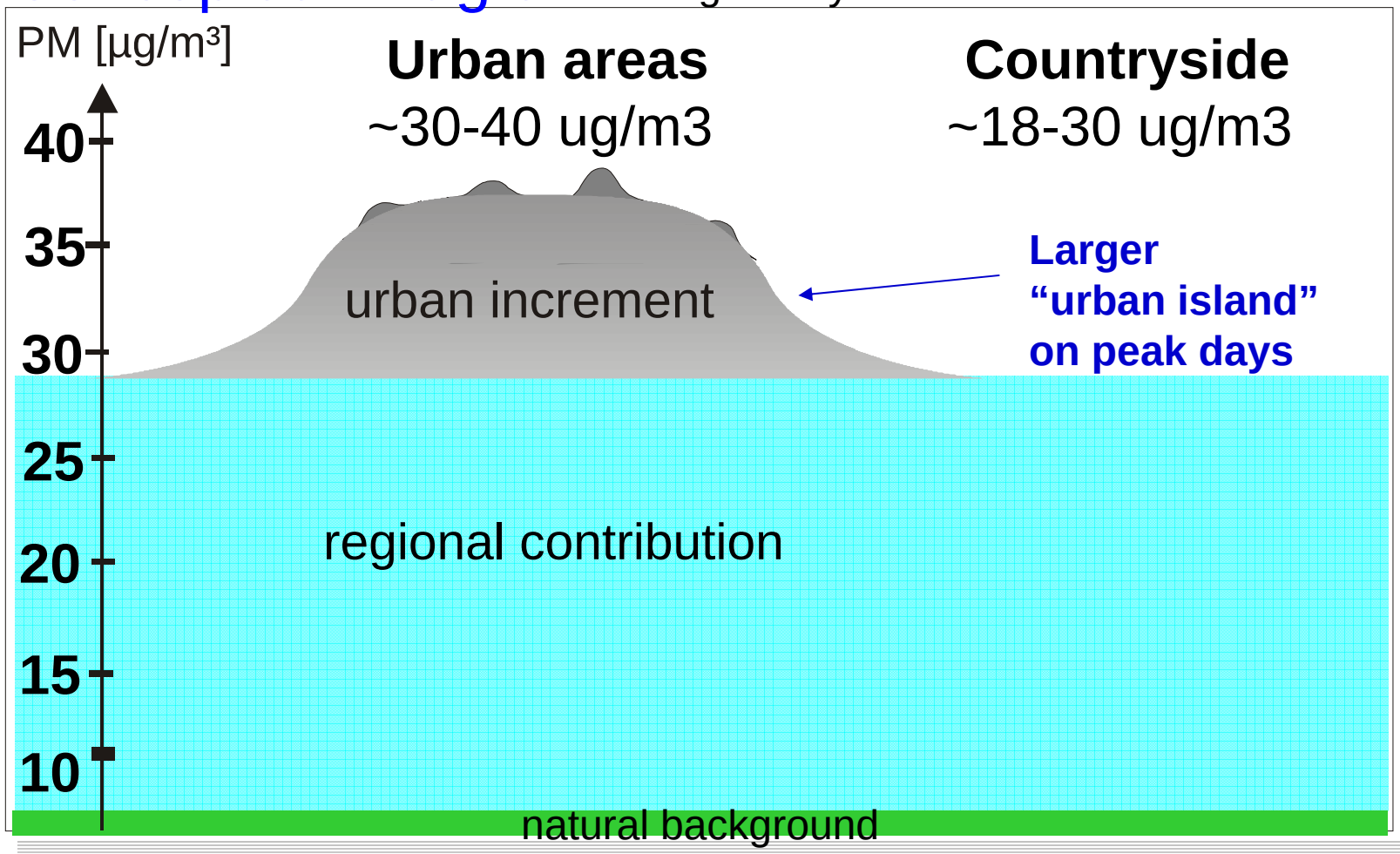
Conceptual Diagram - Annual Average PM2.5



Western US urban areas may have smaller regional contribution

Air Quality - High Daily PM2.5 Concentrations

Conceptual Diagram - High Daily PM2.5 Concentrations



Focus of new analyses: understanding what emissions contribute to urban increment

Western US urban areas may have smaller regional contribution

Conceptual Model for High PM2.5 Days

Source region considerations

Air Quality

Role of Regional vs Urban vs Micro-scale Influences

- On high days particularly in the east, regional emissions often provide a "base" amount of pollution
- Urban-wide and nearby emissions also contribute significantly to high days: "urban island" effect
- In some cases, there may be a micro-scale effect from a single source or small group of sources
  - Does not help define NA boundaries, unless it is the only contributing source

(Note: "urban" can mean large metropolitan area or smaller city)

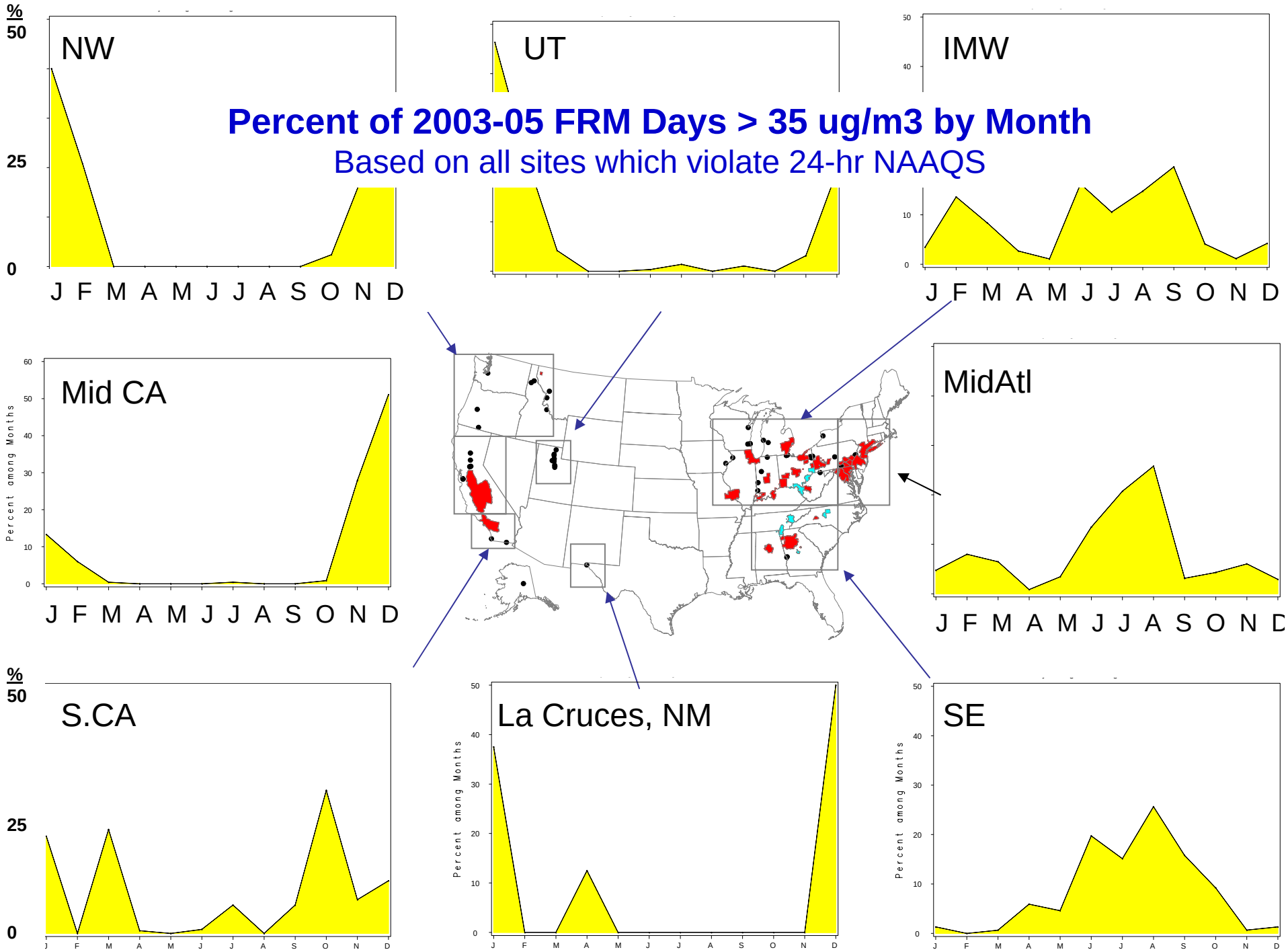
Conceptual Model for High PM2.5 Days

Seasons when exceedances occur

- Time of Year for Exceedances- varies by Geographic Region
  - ***SE***: Mostly summer
  - ***Industrial Midwest (IMW), Mid-Atlantic, So. CA***: Winter and summer
  - ***NW, UT, NM, Middle CA***: Mostly or exclusively Winter

Percent of 2003-05 FRM Days > 35 ug/m3 by Month

Based on all sites which violate 24-hr NAAQS



Conceptual Model for High PM2.5 Days

Composition data are important

Air Quality

Composition

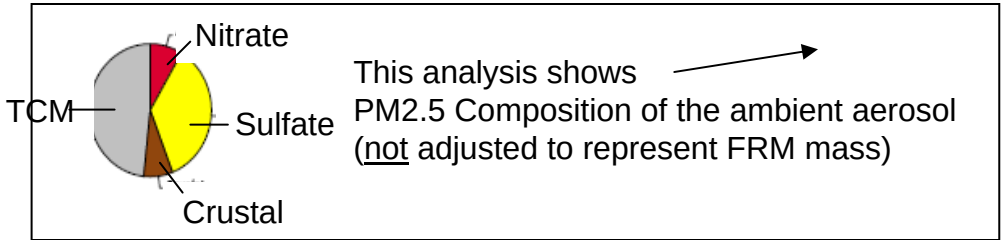
- Indicate which sources are contributing to average and high PM2.5 values
  - Varies across country
- ***Warm season exceedances:*** Mostly sulfate + organic carbon
- ***Cold season exceedances*:** Nitrate (at higher latitudes and in Western US) + sulfate + carbon; Carbon may dominate in some locations (e.g. MT, ID)
- Gaps in speciation data for certain areas

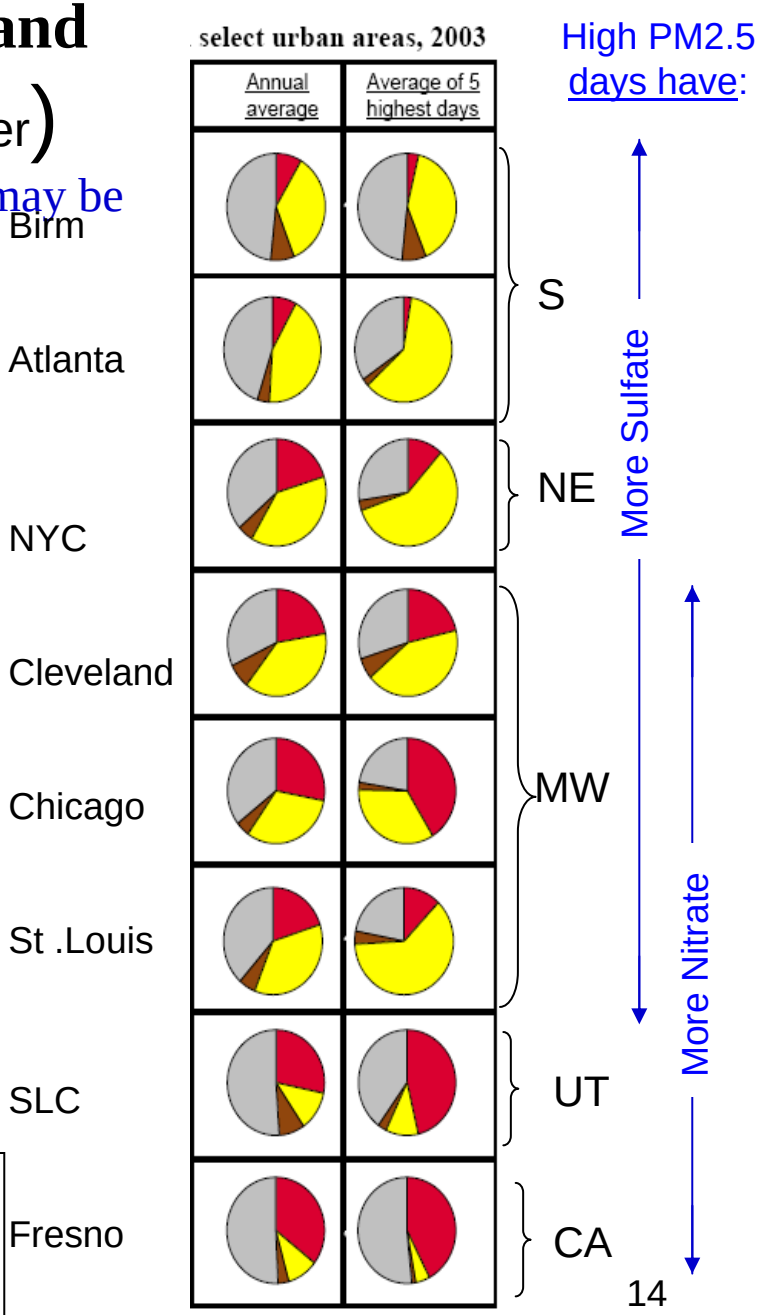
Air Quality

Composition on Annual Average and High PM2.5 Days (From PM Staff Paper)

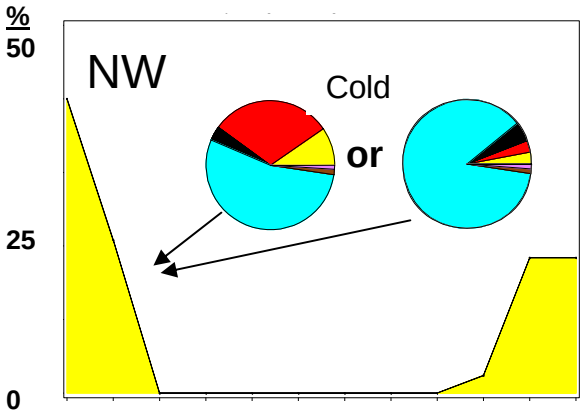
Some source categories and regional influences may be more important for high concentration days

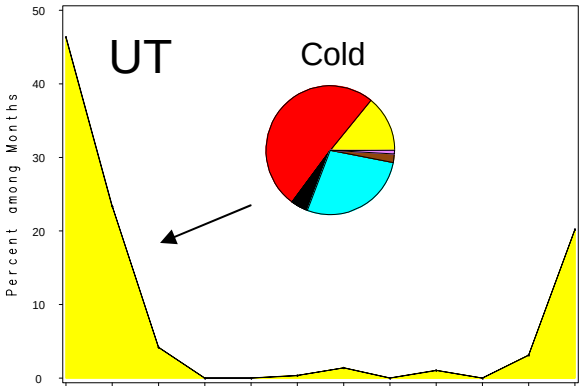
- Comparing average of 5 highest days during 2003, regional sources of sulfates and nitrates are larger contributors to peak day concentrations than to annual average (selected city analysis)
- Composition can vary from high day to high day
- Carbon can be smaller as % -- but still larger in absolute concentration values -- compared to the average
- Note: All the new analyses present "FRM" composition with the p*eer-reviewed "SANDWICH" Technique*
  - *As used in CAIR and PM2.5 RIA*

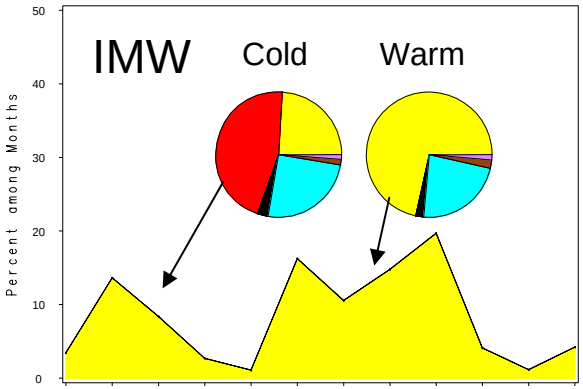




From PM Staff Paper (Rao et al)

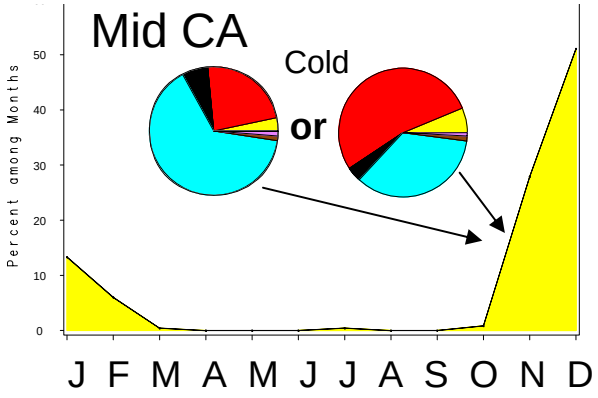


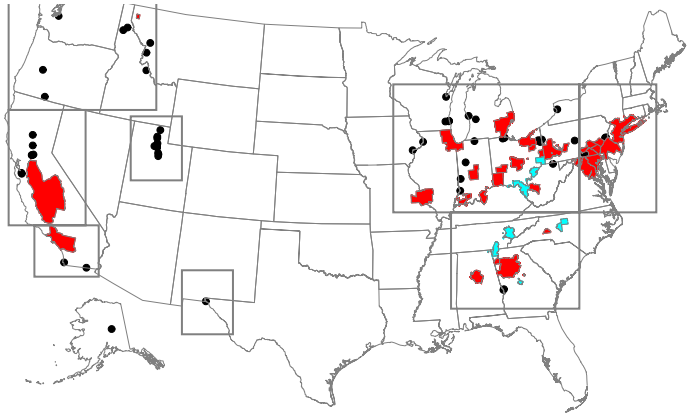


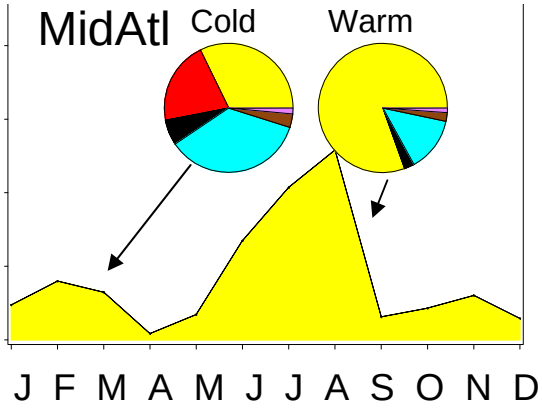


"Example" Composition for High Days ["Warm" Season (May-Sept) & "Cold"]

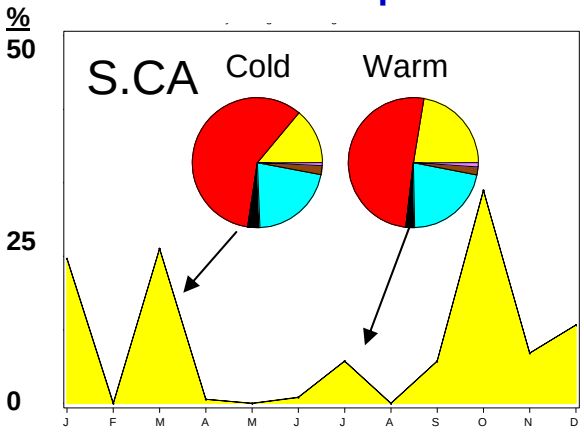
But sites can be different within each "domain"

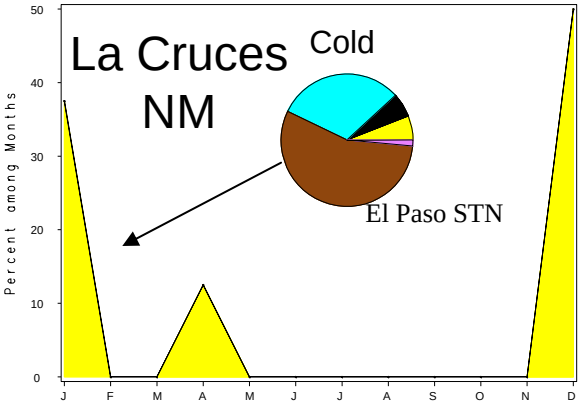


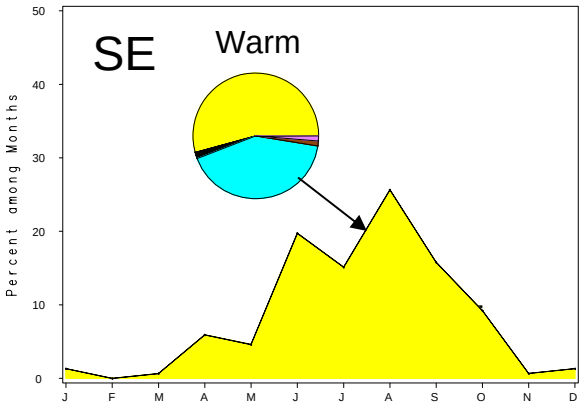




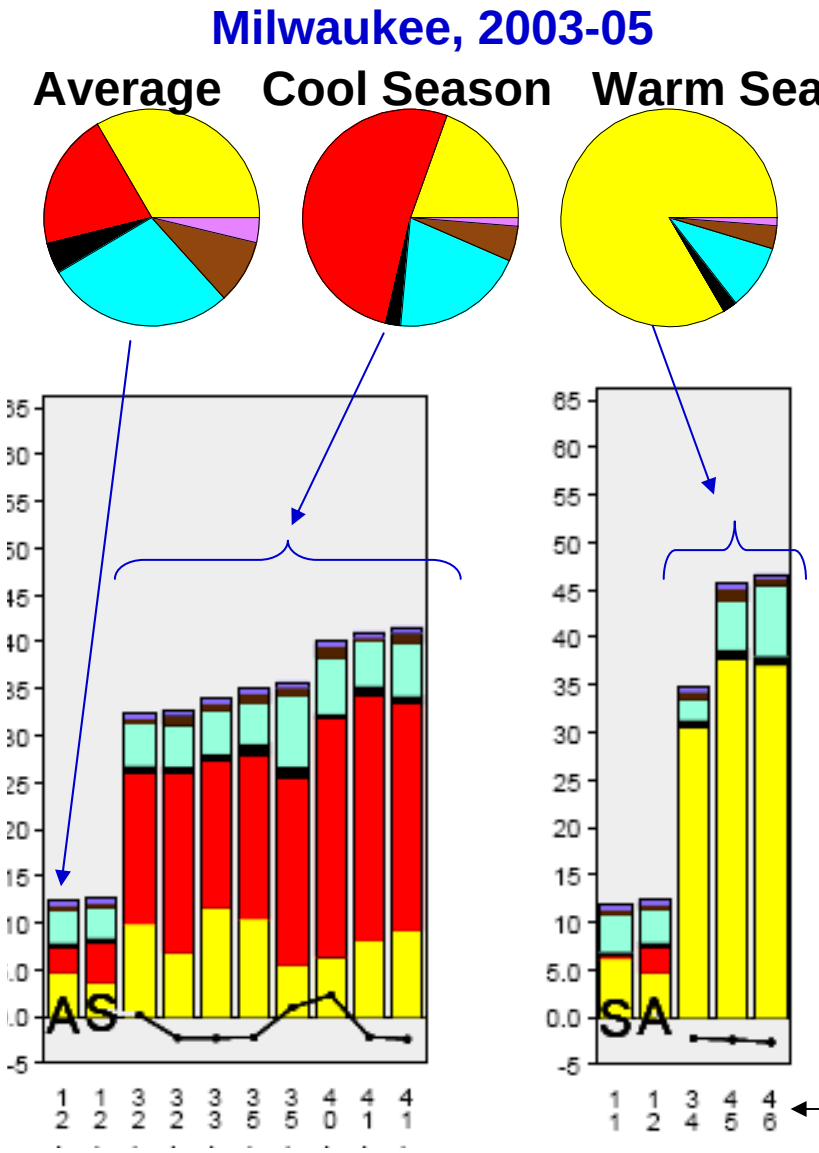
Pies represent average of 3 highest days per year per season, using SANDWICH







Composition is often similar among the high days



3 highest PM2.5 days > 30ug/m3
Per season, Milwaukee, WI (2003-05)

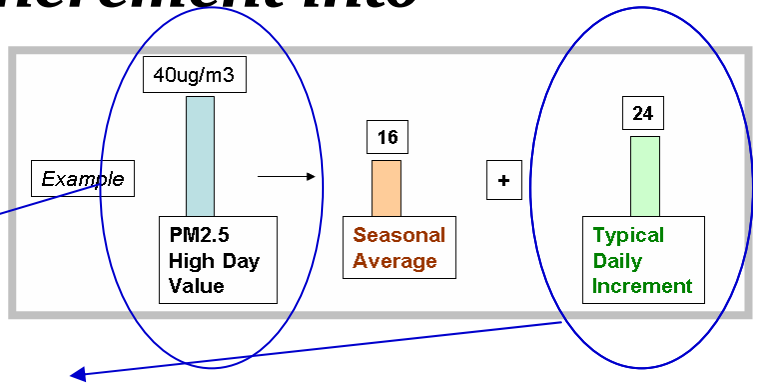
PM2.5 days > 30ug/m3

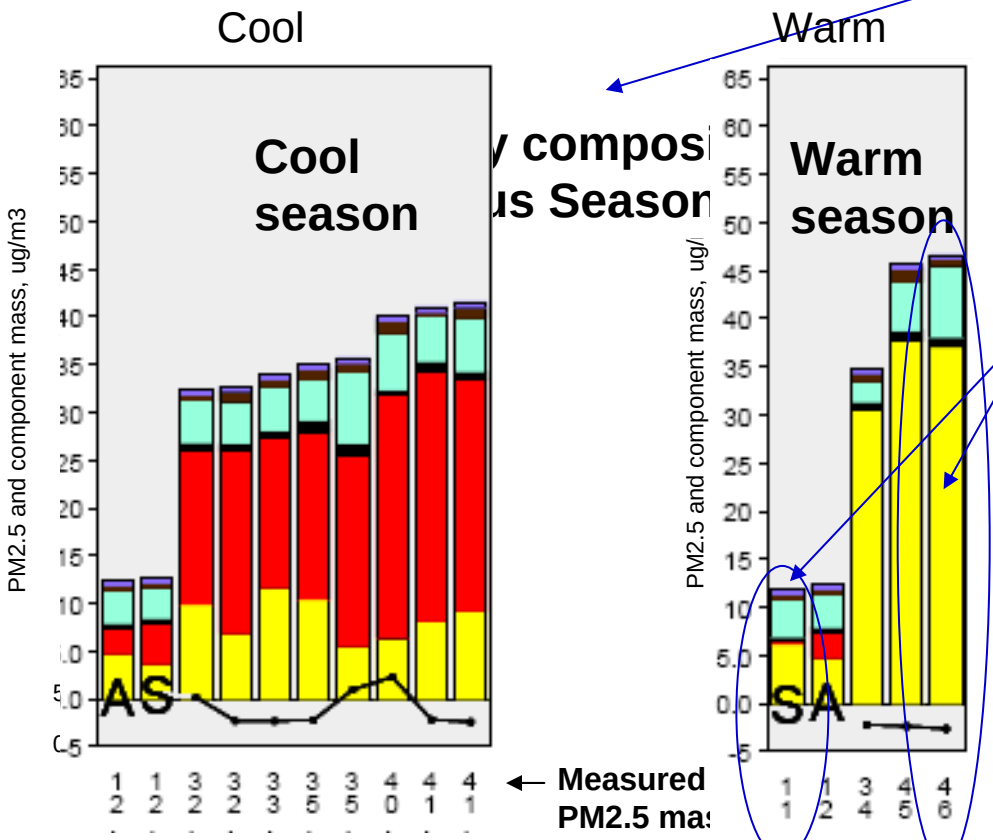
Black line is difference between OCMmb and OCM14

Sulfate_mass
OCMmb
Nitrate_mass
Crustal
EC
Passive

Conceptual Model for High PM2.5 Days

An approach to partition total daily increment into urban and regional components





Next subtract the daily composition from the seasonal average PM2.5

Use *resident time weighted emissions* to partition each component of total daily Increments into urban & regional contributions
(% of RTWE in local area)

Sulfate_mass
OCMmb
Nitrate_mass
Crustal
EC
Passive

The urban background PM2.5 can be estimated using seasonal average PM2.5 concentration of non-high days

PM2.5 days > 30ug/m3
Per season & year, Milwaukee, WI (2003-05)

Analytical Tools

to help identify boundaries and develop SIPs

- SLICE technique - for evaluating urban contributions to high days
- Residence time analysis – for assessing nearby contributing source regions using back trajectories and emissions data
- Urban gradient analysis – for identifying whether there are any sites predominantly affected by a single source

Analytical Tools

Identify urban PM2.5 and gradients

Air Quality

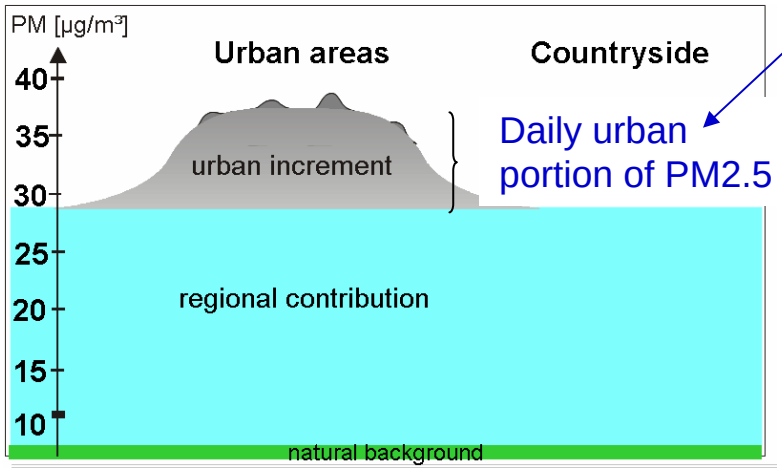
- "SLICE" to identify "urban island" days and relative urban amount of PM2.5 mass
  - Evidence of urban source contributions

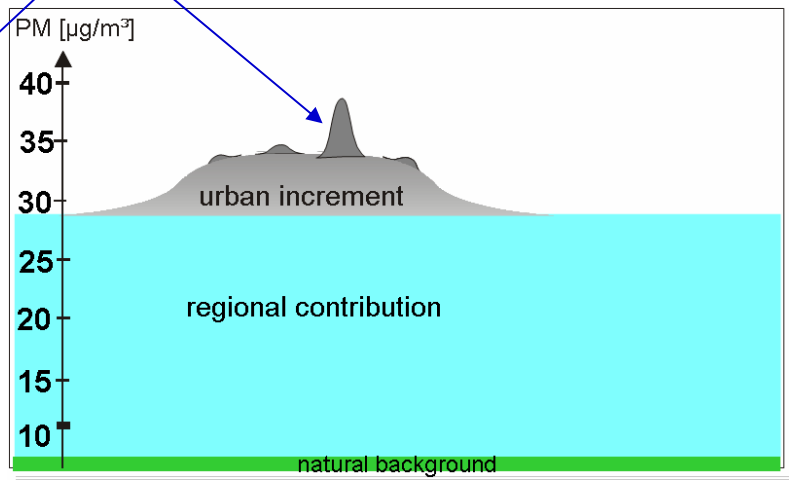
Air Quality

- Urban "gradient" technique

Emissions Met

  - Evidence of predominant strong nearby source influence





Analytical Tools - Residence Time Analysis

Where did the air parcel come from on high concentration days?

Met

Air Quality

Transport patterns producing a potential source region

- Use trajectories and “Residence-Time Analysis” to find upwind probability fields.
- For PM2.5 mass or its components
  - Focus on the ensemble of “High PM2.5 days”, by season for subsequent linking to composition pattern.
    - Days with identified “urban islands” are more important
- Local pollution roses (annual vs. high days) would also be helpful to identify nearby sources.

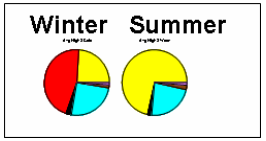
Residence time probability plots with HYSPLIT trajectories have been used by Kinski, Poirot and others to identify potential source regions.

What are the most likely contributing emissions?

Emissions

Spatial distribution of emissions by season

- Developed from monthly emissions for precursors and direct PM: (SO2, NOx, Carbon, Crustal)
- The importance of each precursor pollutant can be guided by the composition of the high PM2.5 day.
- consider monthly emissions corresponding to the affected PM component according to typical composition by season.
- Some precursors will not be considered or could be down-weighted. e.g. crustal (year-round) and NOx (summer).



Met

Emissions

Air Quality

Residence time weighted emissions

- Use probability that air parcel passed over an area to weight emissions as potential contributors to the high day concentration impacts
- High probability nearby contributing emissions can be identified for each PM2.5 contributor

Summary

- Identifying the area of emission influence considers contributions for
  - each “high PM2.5 day” and
  - urban average background on top of which are the daily impacts
- High concentration days with evidence of urban influence (i.e. with urban islands) are more important
  - The magnitude of urban island can help define the daily urban contributions.
- In combination with daily and average speciation data, by season of the year
  - Emissions with high probability of trajectory residence time are important to assess high day impacts.
  - Average emissions and typical wind patterns help understand the sources contributing to the urban “background”
  - Both used to understand the relative importance of the various nearby contributing emissions (e.g. direct PM vs SO_2 vs NOx).